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FINITE ELEMENT ANALYSIS OF FIBRE REINFORCED ELASTOMERIC BEARINGS WITH DIFFERENT ASPECT RATIO

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Abstract-*Elastomeric bearings are amongst the most commonly used devices for seismic isolation. It comprises of a flexible material and a reinforcing material. Conventionally steel is used as reinforcing material. Nowadays different fibre reinforced polymers (FRP) which have strength comparable to steel are developed. By replacing steel by fibre , we can obtain light weight bearing and also the manufacturing becomes easier. The efficiency and cost of the bearing can be optimized by the considering material as well as the orientation of fibres and also the aspect ratio of the bearing. Here, nonlinear finite element analysis is conducted on twelve layered rectangular fibre reinforced elastomeric bearing under the wall by first applying vertical load and later applying varying lateral displacement along with constant vertical load until it undergoes failure For this bearing with unidirectional and bidirectional fibre orientation and five different aspect ratio is modeled and analyzed using ANSYS software and their response is evaluated. Finally the most efficient and economical elastomeric bearing is identified from the analysis results as bidirectionally fibre oriented bearing with lowest possible aspect ratio which is 1.38 in this study.*

Keywords*: Elastomeric bearing, fibre reinforced, lateral displacement ,aspect ratio, fibre orientation*

I. INTRODUCTION

Many large urban areas are extremely susceptible to the damaging effects of large earthquakes. Cities with thousands of buildings were built prior to implementation of rigorous building codes. Most of them have been constructed considering only vertical load design and with no provision for lateral resistance. It is not easy to demolish or retrofit a structure as it is highly expensive as well as it causes disruption to the occupants. Recent research in seismic protection has resulted in the development of inexpensive seismic isolation systems that can adopted in common buildings such as apartments, hospitals, schools etc.

Base isolation can be defined as a flexible interface positioned between a structure and its foundation for dissociating the horizontal motions of the ground from the horizontal motion of the structure, as result reducing the seismic damage to the structure and its contents. For the base isolation a structure the system makes use of elastomeric bearing, where the elastomer is made either with natural rubber or neoprene . Thus the superstructure is decoupled from the damaging effect caused by the seismic waves on the foundation. Thus the structure gains a fundamental frequency much lower than that of a fixed base structure and the dominating frequencies of the motion of ground.

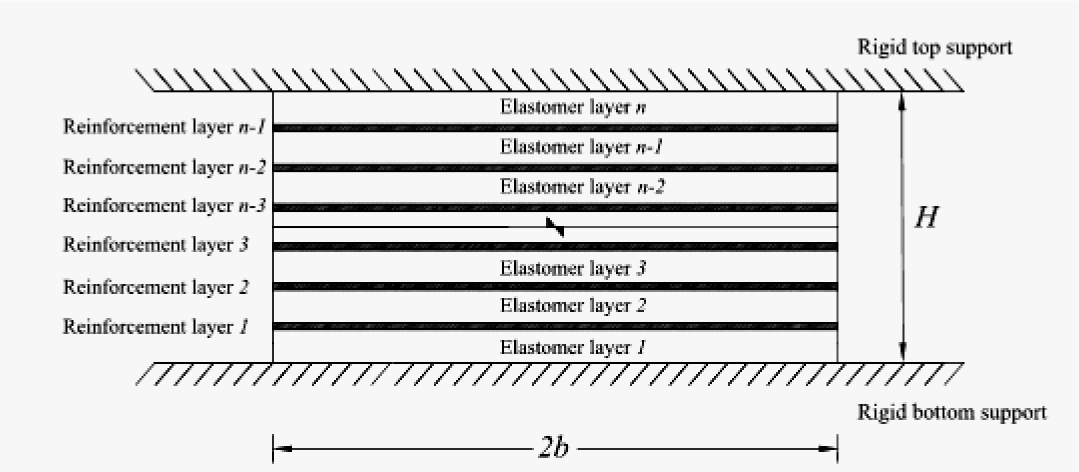

Figure-1 Bearing consisting of n elastic layers bonded to rigid supports **[6]**

The scope of the study deals with non- linear finite element analysis of fibre reinforced elastomeric bearings under the wall with unidirectional and bidirectional fibre orientation as well as with different aspect ratios of the bearing using ANSYS 12.0 software. Further it suggests the most efficient and economic elastomeric bearing.

The objective of present study includes:

- To study the effect of orientation of fibres on the elastomeric bearings.

- To study the effect of fibre reinforced elastomeric bearings under the wall with different aspect ratios.

II. METHODOLOGY

2.1 Modeling in ANSYS

The fibre reinforced twelve layered rectangular elastomeric bearing is modeled through ANSYS 12.0, finite element software. The dimensions of the model are given in the Table - 1.

Table-1 Dimensions

PARTICULARS	VALUES
Length	320mm
Width	150mm
Thickness of rubber layer	2.5mm
Thickness of reinforcing layer	1mm

2.2 Material properties

Table - 2 shows the material properties of the model.

Table-2 Material properties

ELEMENT	MATERIAL
Solid 185	Rubber
Shell 63	Steel
MPC 184	Rigid Constraint

Once the dimensioning of the model is provided element types and material properties are assigned. Solid 185 is used to model rubber as it is suitable for modeling of curved boundaries. It favors , hyper elasticity, creep, large deflection and large strain. It also supports orthotropic material properties. Shell 63 is used to model steel which has both bending as well as membrane capabilities. It also permits both in-plane and normal loads. MPC 184- Link/Beam (Multipoint Constraint Element) is used to model a rigid constraint between two deformable bodies or as a rigid component used to transmit forces and moments in engineering applications. The element is suitable for linear, large rotation or large strain nonlinear applications.

2.3 Discretization

Rubber layer is created as volume and meshed using hexahedral mapped meshing. Steel and fiber layer is created as area and mapped meshing is done. The rubber steel interface is defined with nonlinear multi point constraint elements.

2.4 Load and boundary conditions

Nodes are used to impose all loads and boundary conditions to the model. The top and bottom nodes are used for the same. Vertical and horizontal actions are imposed by means of vertical force in Y direction and horizontal displacement in X direction, respectively. Bottom node is fixed and loads are applied at the top node. Table - 3 shows the load and boundary conditions applicable in the case of fibre orientation. The applied displacement increases while considering the aspect ratio until the bearing undergoes failure.

Table-3 Load and boundary conditions

Analysis case	Applied load (F_y) kN	Applied displacement (U_x) mm
I	50	
II	50	30
	50	60
	50	90
	50	105
	50	109

2.5 Comparison of unidirectional and bidirectional fibre reinforced elastomeric bearing

For studying the effect of orientation of fibre layer, rectangular bearing with 12 layer model is selected. Unidirectional and bidirectional orientations are analyzed. Here fibre is modeled as linearly orthotropic material. For carbon fibre reinforced polymer laminates, E_x = 44 GPa, E_y = 44 GPa, E_z = 10 GPa, μ_{xy} = 0.3, μ_{yz} = 0.25, μ_{xz} = 0.25, G_{xy} = 10 GPa, G_{yz} = 5 GPa and G_{xz} = 5 GPa. Next two cases are considered that includes action of bearing under vertical load only and bearing when subjected to lateral displacement along with vertical load. The comparison is done by considering the stress variation in both the cases and by plotting the respective graph.

2.6 Comparison of bearings with different aspect ratio

For the study based on bearing under the wall with different aspect ratios, models with 5 different aspect ratio, but with the same plan area is considered. Here the plan area taken is 65000mm^2.The aspect ratios considered are listed in table-4.

Table-4 Aspect ratios under consideration

Dimensions (mm)	Aspect Ratio
500 x 130	3.84
433.33 x 150	2.88
400 x 162.5	2.46
350 x 185.7	1.88
300 x 216.66	1.38

Here also two cases are considered, that is bearing under the action of vertical load only as well as bearing under the action of lateral displacement along with the vertical load. Then for comparison, stress variation is considered.

III. RESULT AND DISCUSSIONS

3.1 Performance comparison of effect of orientation of fibre layers

First only vertical load is applied representing the bearing subjected to vertical load from the super structure. Table- 5 shows comparison of stresses on unidirectional and bidirectional fibre oriented bearing under vertical load only and figure-2 shows the stress distribution under vertical load.

Table-5 Comparison of stresses of unidirectional & bidirectional orientation under vertical load only

	Unidirectional	Bidirectional
Sx	-1.529	-1.496
	3.979	3.447
Sy	-1.53	-1.498
	0	0
Sz	-1.529	-1.496
	6.405	5.849

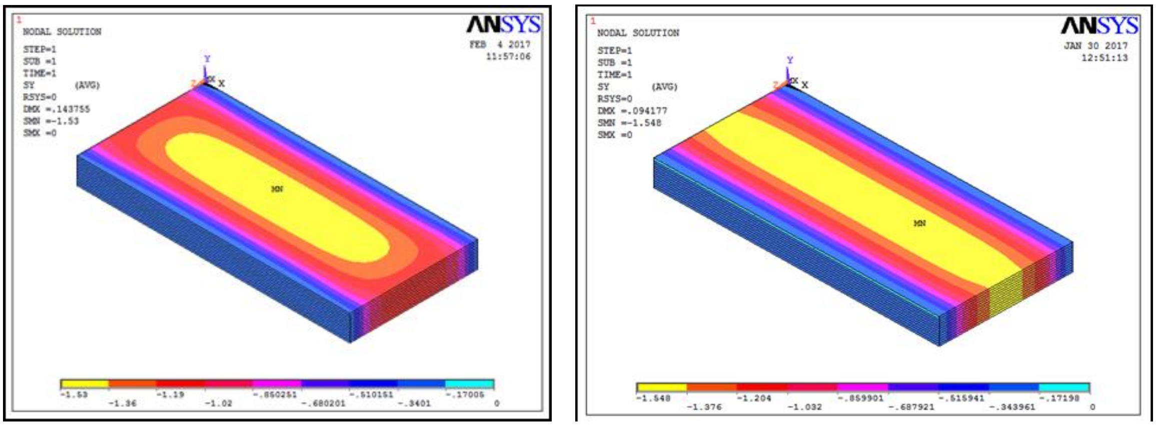

Figure-2 Stress under vertical load in unidirectional and bidirectional fibre orientation respectively

The performance of bearing under lateral load along with vertical force is analyzed by displacement controlled nonlinear static analysis. Lateral displacement corresponding to 100%, 200% etc of shear strain are applied along with the vertical load, until the failure of the model occurs. Table-6 shows comparison of stresses of unidirectional and bidirectional fibre orientation under lateral load and vertical force acting together. And figure-3 shows the respective contour plot.

Table-6 Comparison of stresses of unidirectional & bidirectional orientation under lateral displacement and vertical load

	Unidirectional	Bidirectional
Sx	-11.79	-31.387
	31.64	30.198
Sy	-7.438	-9.276
	6.495	5.184
Sz	-74.559	-74.303
	99.332	97.203
Sxy	-0.123e-14	-0.204e-14
	7.426	7.424
Syz	-0.8435	-0.8347
	0.8435	0.8347
Sxz	-12.465	-12.465
	12.465	12.465

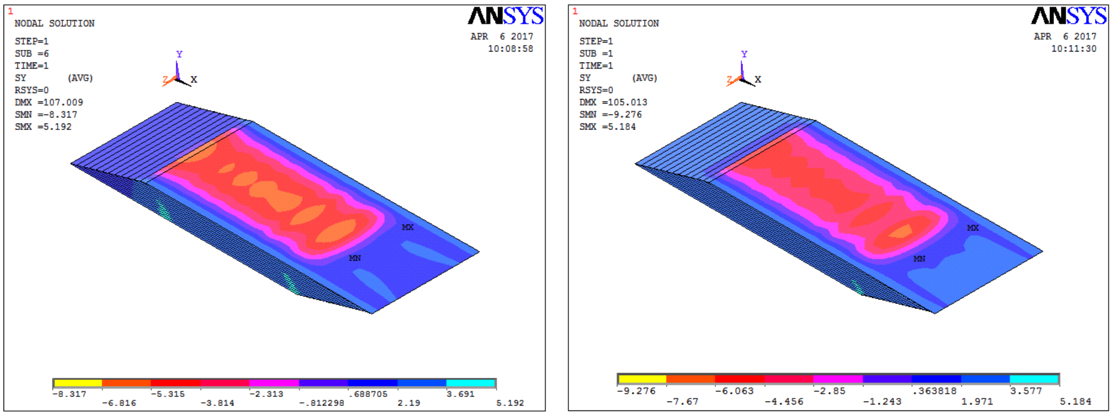

Figure-3 Stress under vertical load and lateral displacement in unidirectional and bidirectional fibre orientation respectively

The contour plot in figure-3 shows the stress variation in both unidirectional and bidirectional fibre orientation. Now figure-4 shows the graph plotted based on this stress comparison.

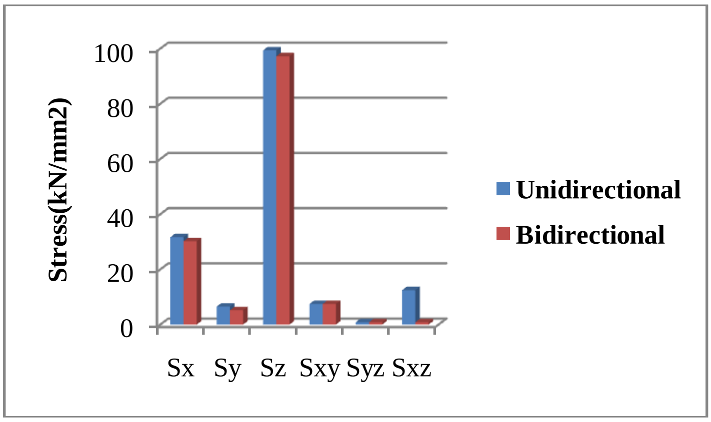

Figure-4 Stress comparison between unidirectional and bidirectional fibre orientation

From the stress comparison and contour plot, it is clear that when the fibre is unidirectional, it is subjected to more stress. Therefore when the fiber orientation is bidirectional, the bearing can sustain more lateral displacement than the unidirectional. That is bidirectional can withstand up to 109mm displacement whereas unidirectional can withstand only up to 108mm without failure. From the displacement controlled non linear static analysis, it is concluded that bidirectionally fiber oriented bearing can withstand higher shear strains(363%) than unidirectional (360%) .

3.2 Performance comparison between bearings with different aspect ratio

As mentioned earlier, the plan area is kept constant, that is 65,000 mm^2 and the dimensions are varied so as to determine the better aspect ratio. Here the cases considered are bearings with aspect ratio 3.84, 2.88, 2.46, 1.88 and 1.38 based on same plan area. First only vertical load is applied and the stress distribution noted.Table-7 shows the comparison of vertical stresses for different aspect ratio. Figure-5 shows a graph plotted based on stress comparison between the bearings with different aspect ratio when it is subjected only to vertical load.

Table-7 Comparison of stresses for different aspect ratio

	3.84	2.88	2.46	1.88	1.38
Sx	-1.112	-1.102	-1.097	-1.086	-1.068
	2.513	2.503	2.508	2.492	2.475
Sy	-1.113	-1.104	-1.098	-1.086	-1.068
	0	0	0	0	0
Sz	-1.112	-1.103	-1.097	-1.086	-1.068
	4.363	4.293	4.245	4.152	4.024

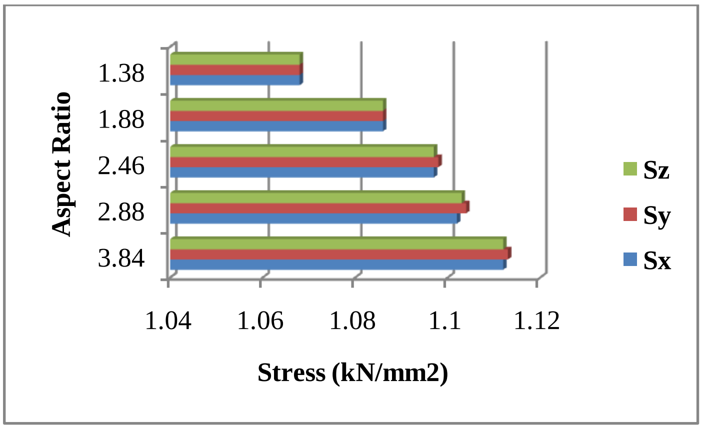

Figure-5 Stress comparison under vertical load for different aspect ratio

From the comparison of stresses, it is seen that stress increases with increase in aspect ratio. So the next case is to be considered. That is when the bearings are subjected to both vertical load and lateral displacement. when this is the case, the deformation developed in the bearings are clearly visible from the contour plots. Figure-6,7 and 8 shows the stress distribution of bearings with aspects ratios 3.84, 2.88, 2.46,1.88 and 1.38 respectively under the vertical load along with the lateral displacement.

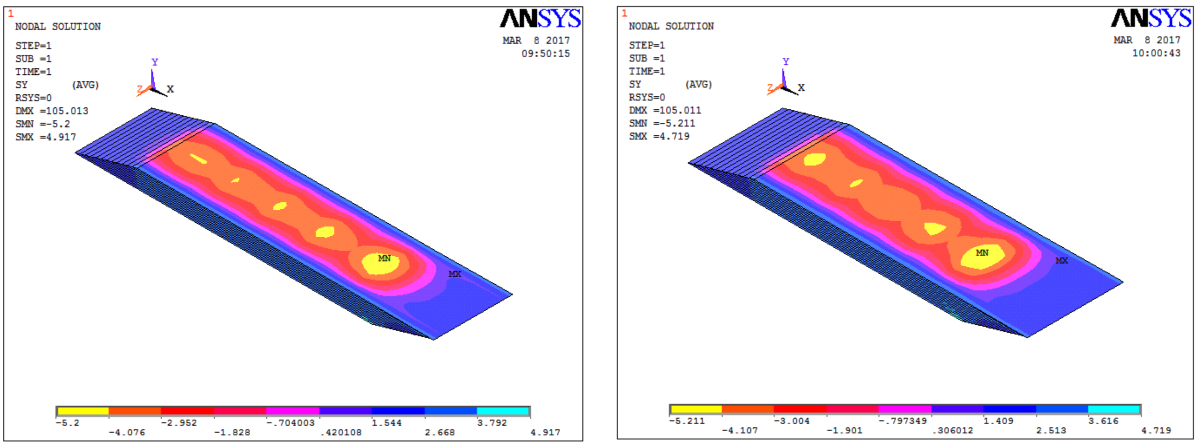

Figure-6 Bearing with aspect ratio 3.84 and 2.88 respectively under vertical load and lateral displacement

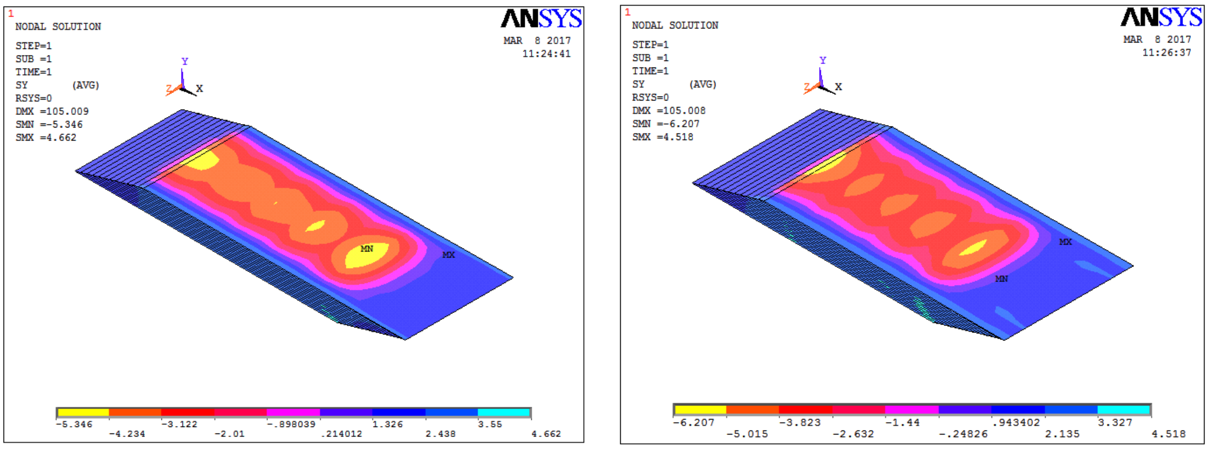

Figure-7 Bearing with aspect ratio 2.46 and 1.88 respectively under vertical load and lateral displacement

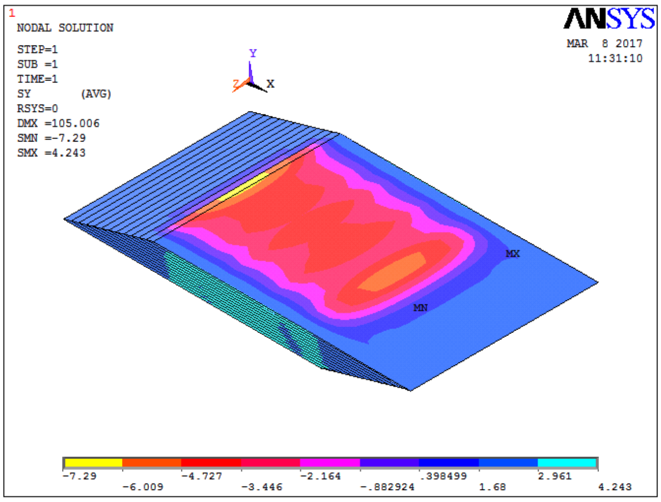

Figure-8 Bearing with aspect ratio1.38 under vertical load and lateral displacement

Next the stress comparison was done by plotting table-8 which again shows that stress value is greater for bearings with greater aspect ratio and then the horizontal force v/s horizontal displacement graph plotted from the time history post processing shown in fig-9 makes it clear that the bearing with lower aspect ratio can withstand more shear force than the ones with higher value.

Table-8 Comparison of stresses for different aspect ratio under vertical load and lateral displacement

	3.84	**2.88**	**2.46**	**1.88**	**1.38**
Sx	-28.281	-24.305	-22.719	-24.025	-24.826
	29.819	29.657	29.618	29.494	29.238
Sy	-5.2	-5.211	-5.346	-6.207	-7.29
	4.917	4.719	4.662	4.518	4.243
Sz	-96.128	-68.513	-54.503	-39.181	-29.013
	120.561	90.911	76.014	58.664	47.356
Sxy	-.19E-15	-0.15E-15	-0.14E-50	-0.15E-15	-.16E-15
	7.49	7.412	7.383	7.364	7.345
Syz	-0.8927	-0.8026	-0.7543	-0.6788	-0.5977
	0.8927	0.8026	0.7543	.6788	.5977
Sxz	-11.603	-9.446	-8.32	-6.79	-5.326
	11.603	9.446	8.32	6.79	5.326

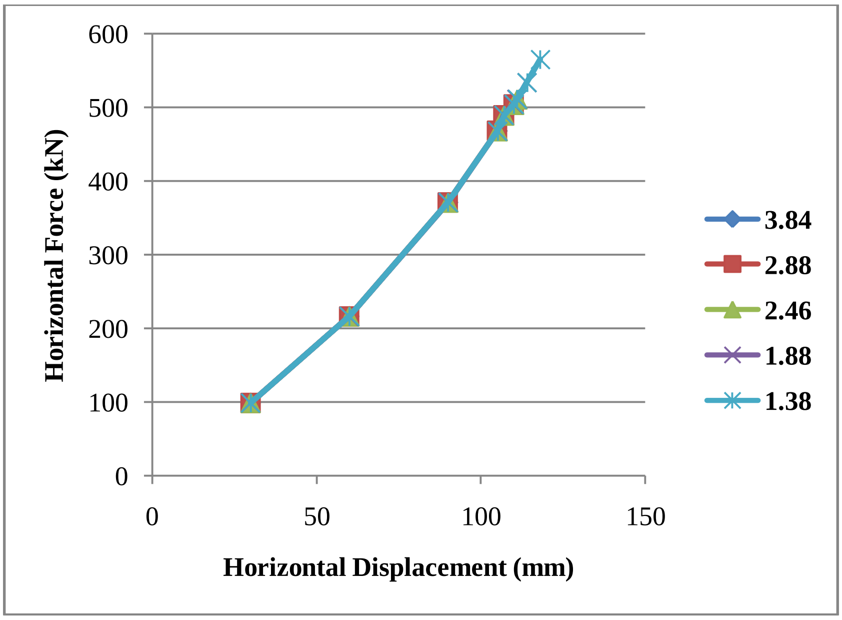

Figure-9 Horizontal Force v/s Horizontal displacement for different aspect ratios

So from the comparative study, it is clear that the peak shear strain value in the bearing with lower aspect ratio is greater than the shear strain value in the elastomeric bearing with greater aspect ratio.

IV. CONCLUSIONS

Elastomeric bearings with steel as reinforcing material are usually used for seismic protection in base isolation. Replacing steel laminates with fibre sheets makes base isolation a more economic technique.

From the present study, the conclusions arrived includes that the bearing was subjected to 100% vertical load and a horizontal displacement up to 400% shear strain. But it was noticed that the material did not remain stable until then and the elements were found to be highly distorted.

In the case of orientation of fiber, when the fiber orientation is bidirectional, the bearing can sustain more lateral displacement than the unidirectional. That is bidirectional fibres can withstand up to 109mm displacement whereas unidirectional can withstand only up to 108mm without failure. From the displacement controlled nonlinear static analysis, it is concluded that bidirectional fibre oriented bearing can overcome higher shear strains(363%) than unidirectional(360%) fibre oriented bearing. So it is learnt that when unidirectional fibre layer is used, the bearing couldn't sustain the shear strain as much as that of bidirectional laminates and the stress values were greater. This is because, stiffness of unidirectional fibre in X direction is greater than in the other two directions of bidirectionally oriented fibres. So bearings with bidirectional fibre laminates provide better performance.

Finally considering the aspect ratio, among the five cases considered bearing with greatest aspect ratio that is 3.84 was observed to withstand up to 357% lateral displacement and bearing with lowest aspect ratio that is 1.38 could withstand up to 393% lateral displacement. So it is clear that when the aspect ratio decreases, the bearing would withstand more horizontal force. Thus the peak shear strain value in the bearing 1.38 was observed to be 36% greater than the bearing with 3.84 aspect ratio.

So the final conclusion of the study is to adopt bidirectionally fibre oriented elastomeric bearing under the wall for better seismic protection of a structure.

REFERENCES

[1] Arya G and Mathai A, "Nonlinear finite element analysis of high damping rubber bearings for base isolation", *International journal of civil engineering and technology*, 5,252-259, 2014.

[2] Bhoje S.B, Chellapandi P, Chetal S, Muralikrishna R and Salvaraj T, "Comparison of computer simulated and observedforce deformation characteristics of anti-seismic devices and isolated structures", Indira Gandhi Centre for Atomic Research, India,1998.

[3] Gaetano R and Margherita P, "Sliding instability of fiber-reinforced elastomeric isolators in unbonded applications" , *Engineering Structures* 48, 70–80,2013.

[4] Gaetano R, Margherita P and Andrea C, "A study on experimental shear behavior of fiber-reinforced elastomeric isolators with various fiber layouts, elastomers and aging conditions", *Engineering Structures*,52,422–433,2013.

[5] Kelly J M and Takhirov S M ,"Analytical and experimental study of fiber-reinforced strip isolators", *Earthquake Engineering Research Center*, 6,19-33,2012.

[6] Osgooei P M, Michael J. T, Konstantinidis D, "Finite element analysis of unbonded square fiber-reinforced elastomeric isolators (FREIs) under lateral loading in different directions", *Composite Structures* 113, 164–173,2014.

[7] Subramani T, Jothi J and Kavitha M, "Earthquake Analysis of Structure by Base Isolation Technique in SAP", *Int. Journal of Engineering Research and Applications*, 4,.296-305,2014

[8] Kelly J M, Calabrese A and Serino G, "Design criteria for Fiber Reinforced Rubber Bearings", Lisboa, *WCEE*,1-10, 2012.

